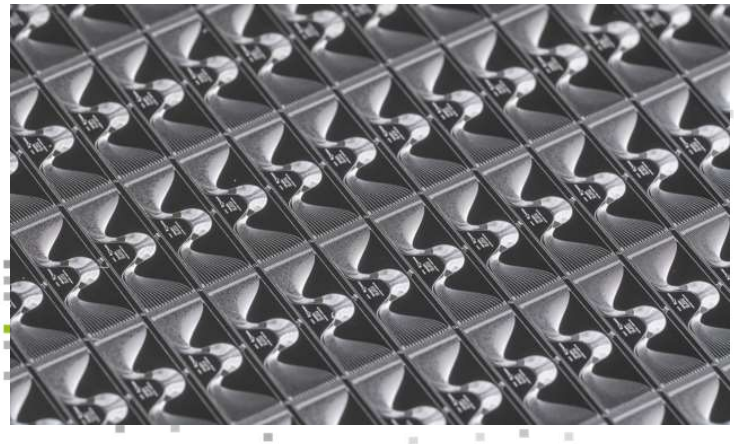


ON-CHIP OPTICAL SENSING FOR CHEMICAL TRACE DETECTION

Leti @ Semi Workshop | Sergio Nicoletti| February 6th, 2019

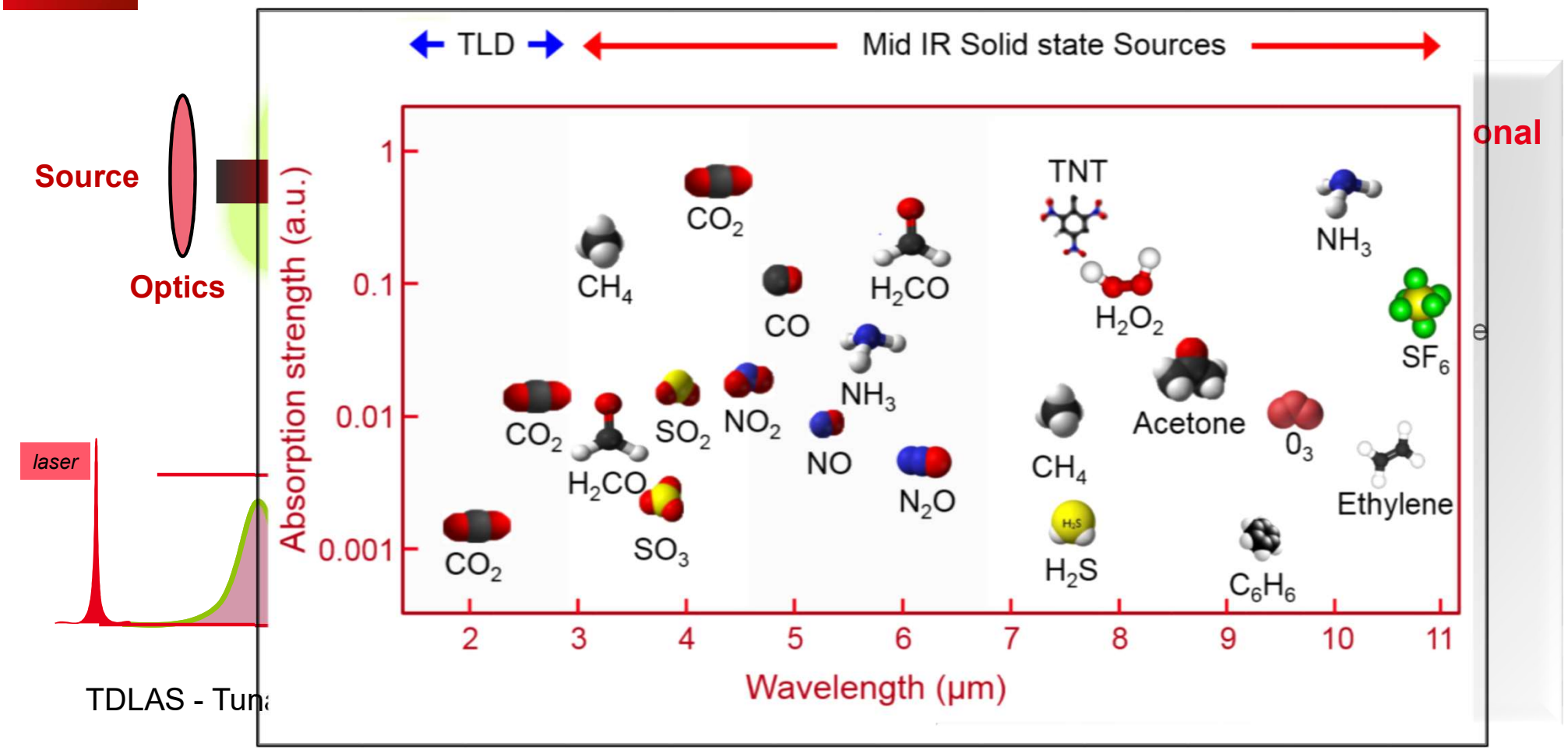
Chemical Sensing Requirements

Chemicals NOx Calibration Stable Measure VOC Real Time Size SOx Turnkey use CO Emissions CO_2

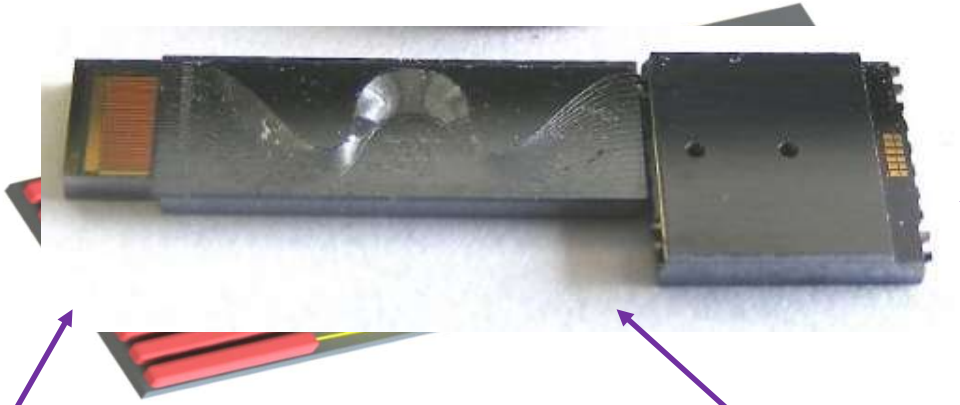
Courtesy from ThermoFisher Scientific

Courtesy from Amazon.com

THE PRINCIPLE OF OPTICAL DETECTION



Concept of Integrated Multigas Sensor on Si



Gas sensing cell – PA detector with MEMS µPhone

Replace bulky multipass cells

Array Quantum Cascade Lasers on Si

Multigas detection enabler

Photonics Integrated Circuit Beam Combiner

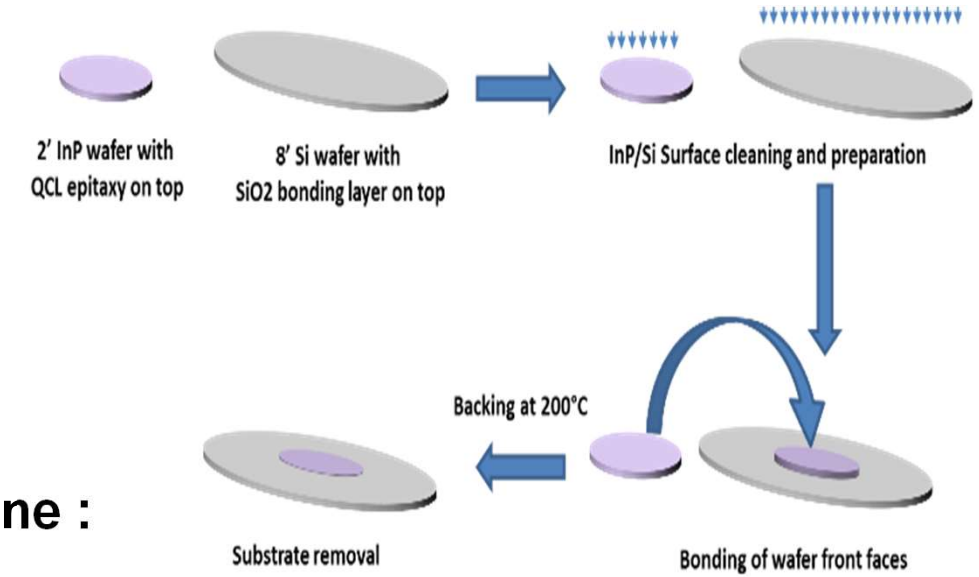
Replace costly and fragile discrete optics

Challenges in the realization of a fully integrated optical lab-on-chip S Nicoletti, P Barritault, S Boutami, M Brun, A Gliere… - SENSORS, 2014 IEEE, 2014

Cascade laser on Si – Leti Approach

- Transfer the III-V stack on the Si
- Manage light coupling
- Electrical injection
- Thermal management

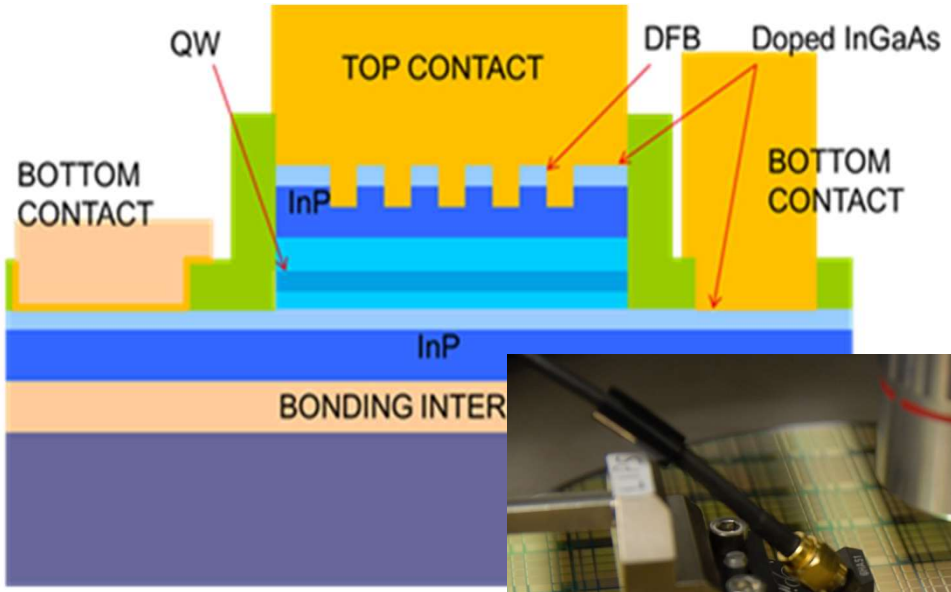
- **Process QCL in 200 mm CMOS pilot line :**
  - ➢ **Increase fabrication yield**
  - ➢ **Improve laser quality**
  - ➢ **Reduce cost**

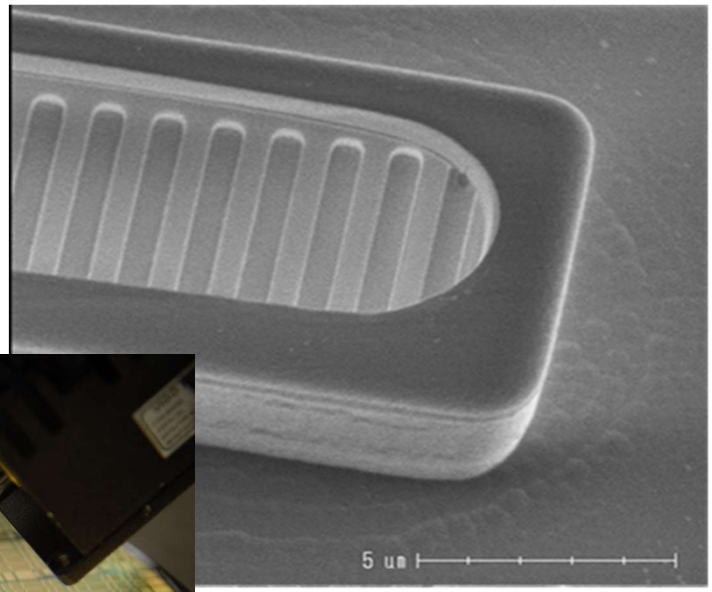


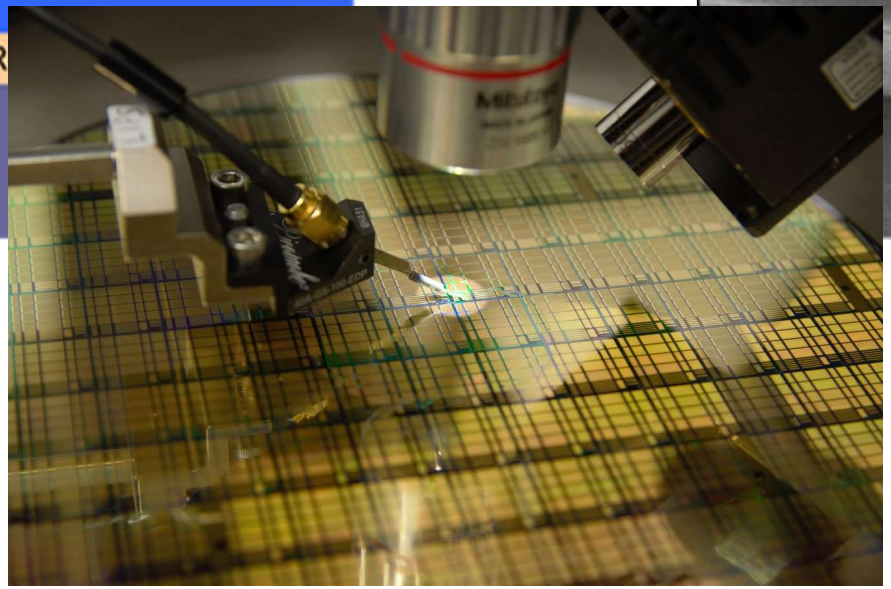
InP Wafers with QCL epilayers

Fraunhofer IAF

Cascade laser on Si – Leti Approach







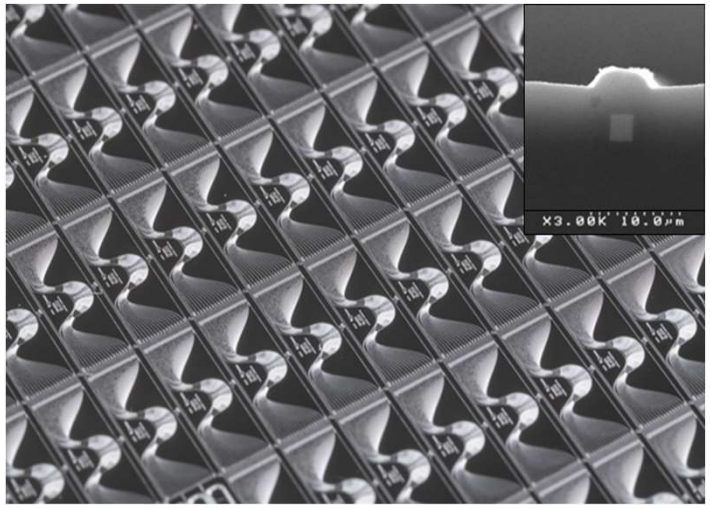
C-MOS compatible process

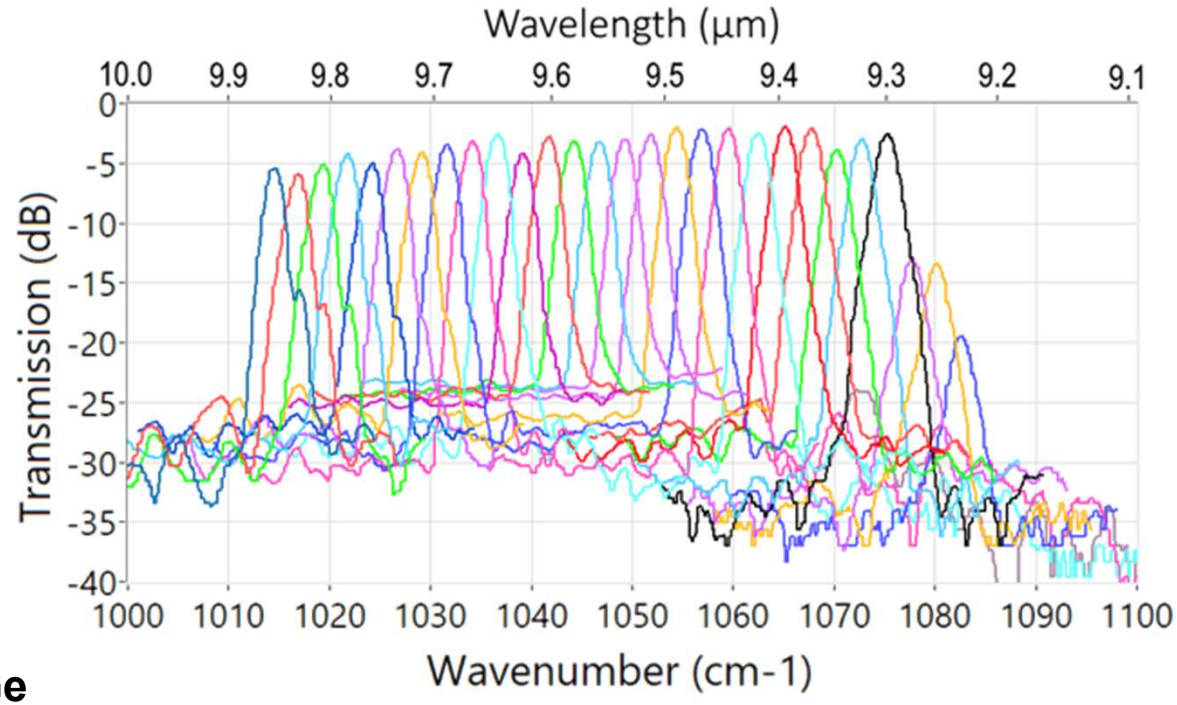
Std. IC technology

Wafer level test

98% Yield

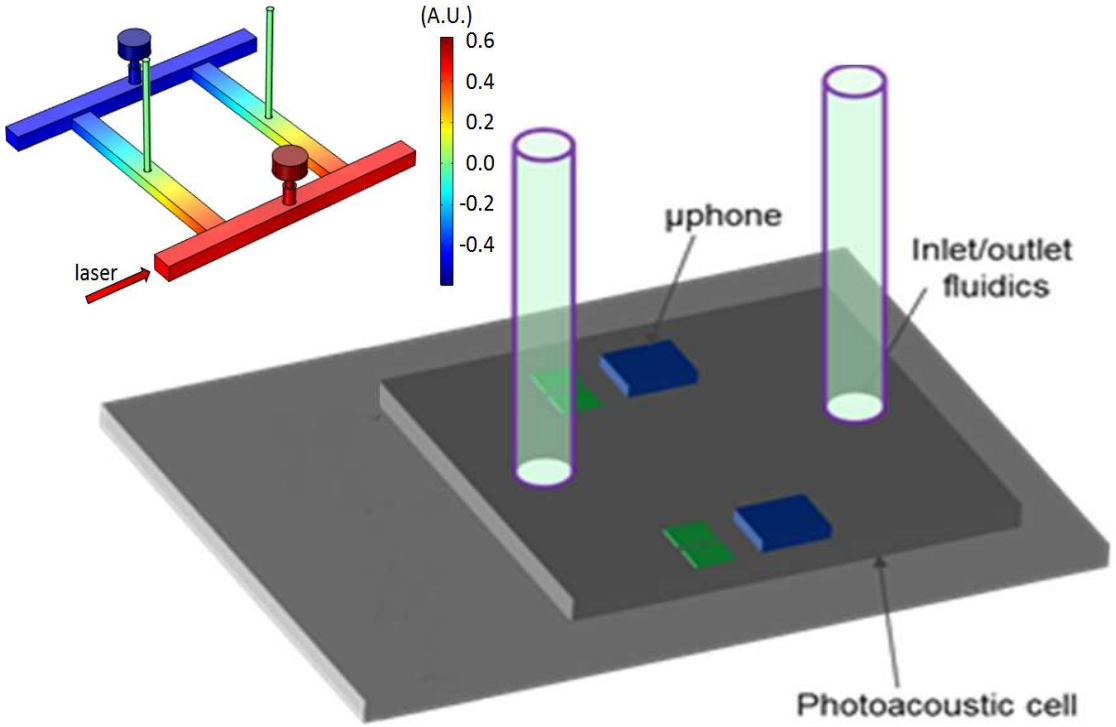
Mid-IR Integrated Photonics

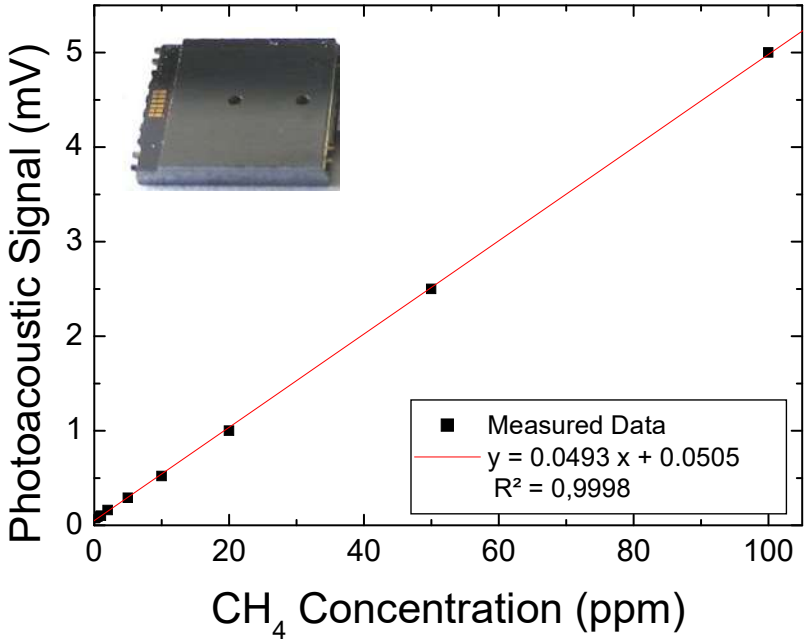




- **Si/SiGe/Si & SiGe/Ge/SiGe**
- **Wavelength band coverage: 3 to 10 µm**
- **Technical topic: AR coating to reduce the injection losses**

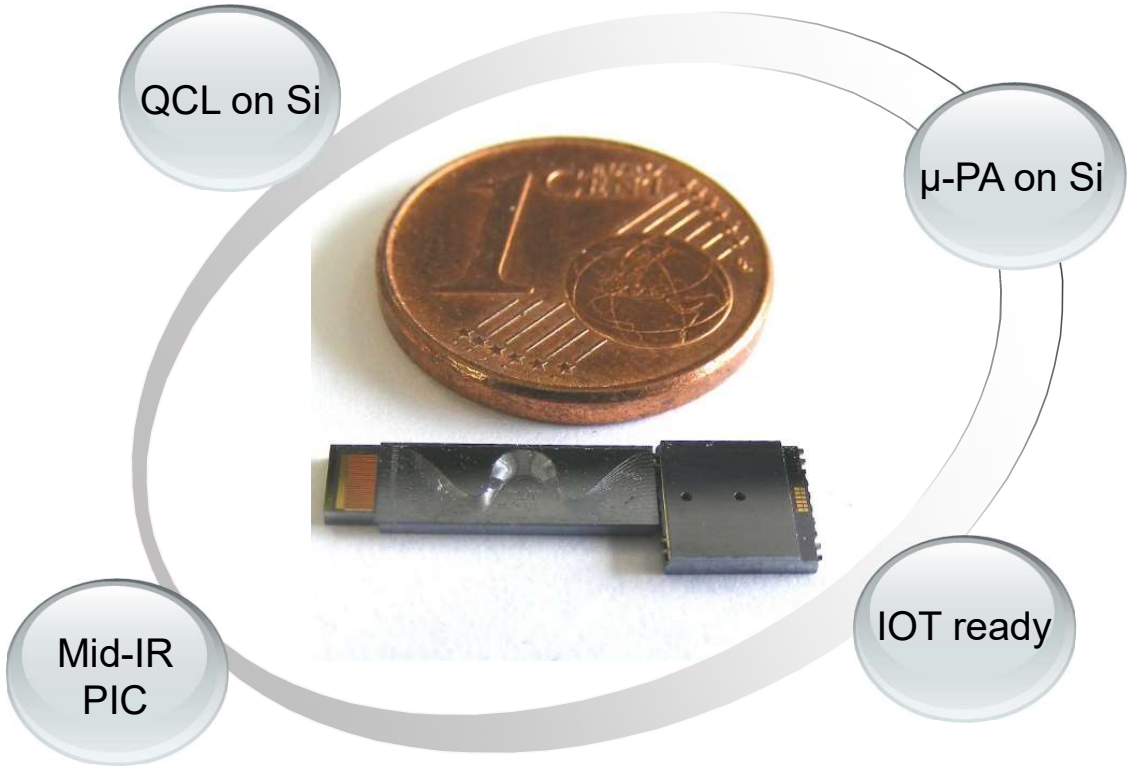
Si Photo-Acoustic cell





From 100 ppm down to ppb

On-Chip PA Sensors – Takeaway



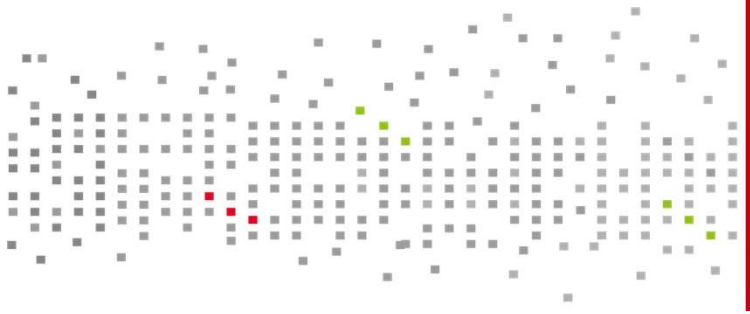
Industry
Process control
Emission monitoring

Defense
Hazardous chemical detection

Healthcare
Breath analyses
Early diseases detection

Environment
Air quality monitoring

Thank you for your attention



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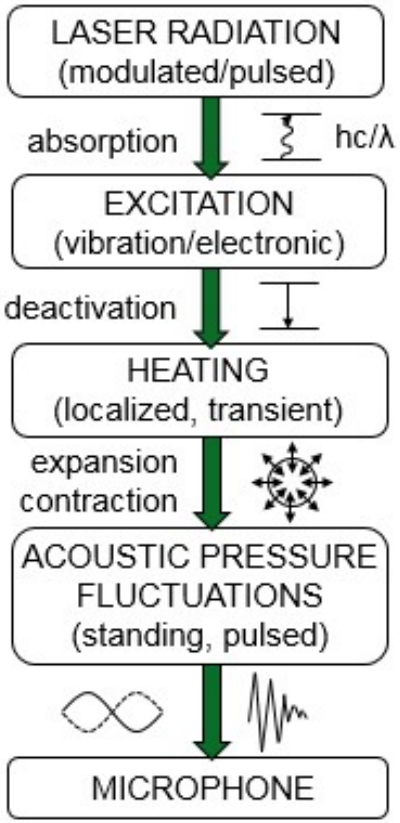
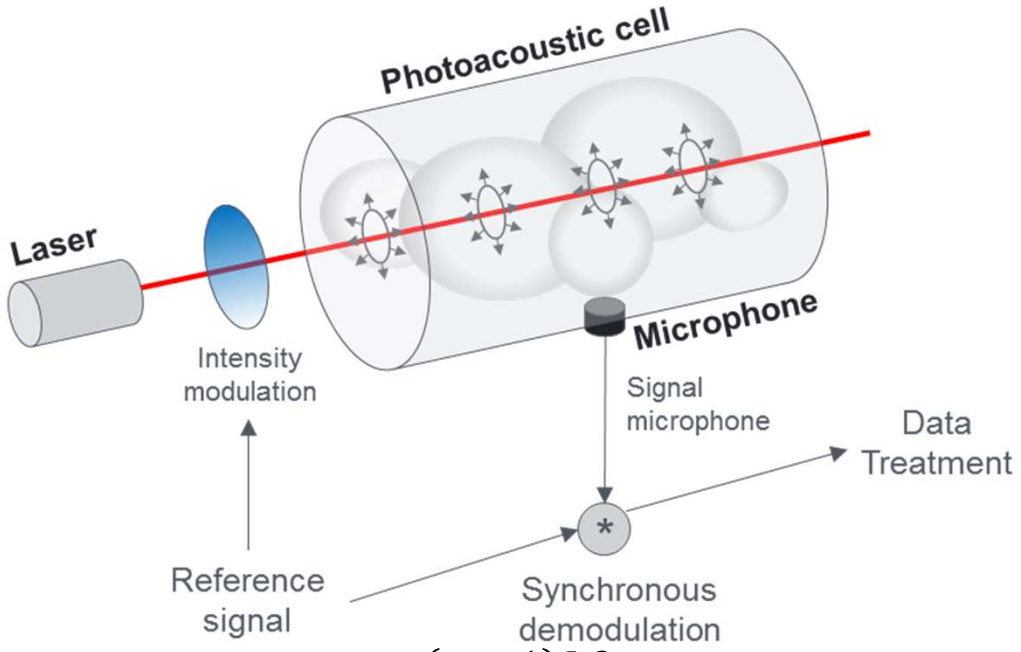
Minatec Campus | 17 avenue des Martyrs | 38054 Grenoble Cedex | France
www.leti-cea.com

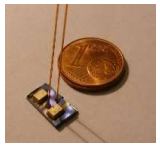
PhotoAcoustic detection



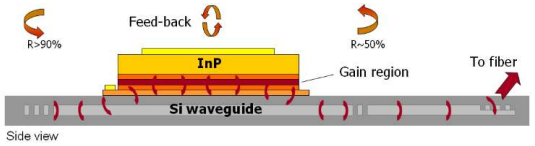


$$S_{PA} = \frac{(\gamma - 1)LQ}{\omega V_C} R_M P_0 \alpha$$

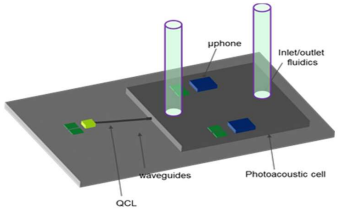
TIMELINE



✓ PA Gas detector on Si



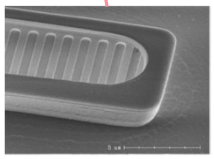
QCL on Si – evanescent coupling



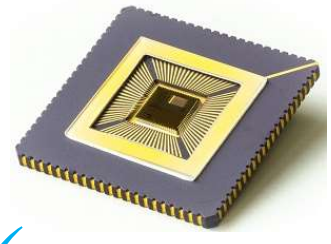
PA sensor on chip – One chemical

2017 | **2018** | **2019** | **2020** | **2021** | **2022**

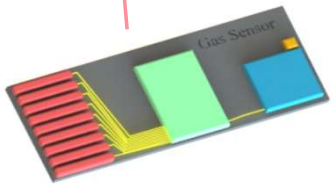
✓ PA Gas detector by 3D Printing



✓ QCL on Si – Ver. 1



✓ On - chip Particle Matter (PM1) sensor



Multi gas PA sensor fully integrated on Si